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# Public preferences for ecosystem services on exurban landscapes: A case study from the Mid-Atlantic, USA

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## Abstract

This paper reports data from a residential landscape preference study conducted in Delaware, USA. The researchers constructed an ecologically designed exurban residential landscape, which delivered 20 new environmental and human-related impacts, including 7 that delivered ecosystem services. Ecosystem services included impacts such as improved flood control and enhanced plant diversity. Using pictures before and after the intervention, an intercept survey of 105 non-neighboring residents estimated whether the 20 impacts positively, negatively, or did not affect the respondents' household wellbeing. The public found that most landscape-intervention impacts had a positive effect on their quality of life, especially those impacts involving ecosystem services. All but one ecosystem service were found to be strong amenities and the other (moving indoor activities outside) was an amenity. However, the landscape intervention delivered one clear disamenity: increased undesirable wildlife. Respondents also identified what impacts were the most important in affecting their welfare: undesirable wildlife (negative); flood control (positive); and water quality (positive). Ecosystem services accounted for 41.6% of the public's importance rating, while undesirable wildlife was 12.9%. A planning process seeking more ecosystem services from

residential landscapes should focus on all the most important drivers of preference, if it is to be accepted by residents.

Keyword: Economics

## 1. Introduction

This research explores public perception of ecosystem services (ES), i.e., the goods and services received from natural resources contributing directly and indirectly to human welfare (de Groot et al., 2002). Specifically, the study focuses on public preference for a range of research-based amenities relative to a particular ecologically designed landscape. Researchers developed a comprehensive list of the outcomes of an ecologically designed landscape provides and measured public perceptions of how these outcomes impacted survey respondents' quality of life. The outcomes are termed "impacts" because they impact human well-being, and the impacts capture the economic concept of utility as measured positively (an "amenity") or negatively (a "disamenity").

Perception informs how people behave and make decisions related to their personal finance, comfort, safety, as well as their overall welfare. Perception of risk or safety is critical in the socio-political context within which policy makers operate, ultimately driving support or opposition (Leiserowitz, 2006). Homeowners and policymakers who perceive a landscape treatment as beneficial or ecologically important may be more likely to press for policies that allow for change. By contrast, landscape treatments that are perceived poorly likely will drive policy that disallows or discourages those practices that are ecologically sound, but misunderstood.

### 1.1. Landscape perception

Long-standing research informs the psychology of landscape perception, the interrelationships between environmental attitudes and landscape preferences, and the drivers of landscape preferences (see Kaplan and Kaplan, 1989; Kaltenborn and Bjerke, 2002; Hands and Brown, 2002). Our study best matches a subset of this literature that seeks to understand landscape preferences in specific locations. Representative studies clarify the various approaches to measuring preferences for urban/exurban ES provision. Survey methods and locations varied: (a) In-person interviews in Arizona, USA, and Aljarafe, Spain (Yabiku et al., 2007; Fernández-Cañero et al., 2011); (b) phone interviews in Ohio, USA (Blaine et al., 2012); (c) written questionnaire surveys in Perth, Australia, and New Mexico, USA (Kurz and Baudains, 2010; Hurd et al., 2006); (d) web image-based survey in Michigan, USA (Nassauer et al., 2009); and (e) mixed interview/questionnaire in West Yorkshire, England (Goddard et al., 2013). The elicitation method also varied. One approach asks (verbally) about perceptions of lawn attributes such as chemical use

and appearance without pictures (Blaine et al., 2012). A second approach asks about homeowners' landscape water use decisions and knowledge (Hurd et al., 2006; Fernández-Cañero et al., 2011; Goddard et al., 2013).

One approach asks respondents to rate pictures of different gardens, relative to certain questions reflecting preference for ecosystem services such as habitat provision or relative to neighborhood norms. Kurz and Baudains (2010) term these residential preference studies, "private domestic urban landscape preference," or PDULP studies. Like these studies, we focus on how neighbors and the broader public perceive landscaping choices on specific lots rather than how homeowners feel about their own landscaping. This offers a consistent construct of utility. We focus on non-homeowner preferences because enhanced ES landscaping—or ecologically designed landscapes—are not currently the norm in exurban developments in the mid-Atlantic, USA, so there would be few owners to sample. In the study region, adoption of ES landscaping will grow slowly, and this research will help policymakers understand how this relatively rare residential management strategy will be perceived.

## 1.2. Ecosystem service impacts

The residential landscape in the mid-Atlantic region largely contains a limited palette of plants and a predominance of mown turf. This "traditional landscape" represents the cultural norm and variations of this landscape are not frequently seen in contemporary subdivisions. Alternatives to this paradigm exist in mature neighborhoods, on stand-alone residential sites, and occasionally in sub-divisions and these contemporary landscapes include less lawn, more trees, more ground-cover, and in some cases residential-scale meadows. "Contemporary landscapes" (CL) have the ability to deliver ES impacts. Clean water is an example of an ES. In a home landscape, contribution to cleaner water occurs by preventing erosion, ensuring water infiltration, and reducing pollution by reducing the amount of lawn. In this example, the ES is achieved locally as a result of changes in a small landscape and results are negligible when compared to the greater landscape; therefore, it is important to understand public perceptions of various strategies used to achieve ES impacts in a CL to determine their relative qualities of many ES impacts. The desired ES improvement will only be achieved on a meaningful scale if many people adopt the practices deployed in the CL.

For the purposes of this study, a demonstration landscape was designed to deliver at least 7 new ES impacts and 13 non-ES impacts in terms of indirect ecosystem effect, management, installation, and aesthetics. The research-based impacts were developed and modified through extensive focus group testing of terminology. Final ES impacts represent statements in terms that are most understandable by the general public and include flood control, improved water quality, increased plant

diversity, lower air temperatures, less energy used, less mowing, and moving indoor activities outside. [Table 1](#) describes the ES impact, how it is delivered in the landscape, and the home landscaping strategy used at the demonstration installation for the purposes of this study.

### 1.3. Other impacts of the landscape intervention

Contemporary landscapes are capable of delivering a broad variety of impacts beyond ecosystem services. Certain impacts have concrete ecological benefits, but others have non-ecosystem service costs or benefits that arise from various installation or management practices including altered aesthetics. Researchers identified non-ES impacts that may have an influence on neighbors and the broader public by directly viewing or drawing benefits from a CL. For example, the provision of habitat may have an unintended cost, as seen from the perspective of many owners, neighbors, and the broader public in that the same habitat that hosts desirable species may also increase the likelihood that undesirable wildlife may be present. In the study region, these animals include snakes, rodents, bees, ticks, and deer. Ecologists argue that these species play important roles in ecosystems and that the risk of human harm or disease is minimal, but pretesting confirmed that this impact was important and mostly perceived to be negative by respondents. To accommodate these two perspectives and to distinguish this impact from the habitat impact of plant diversity, researchers labeled this and other non-ES impacts as “indirect ES” (see [Table 2](#)).

### 1.4. Exurban development

This study focused on a landscape intervention installed at a private residence in an exurban development in Delaware, USA. Exurban is defined as large lot development on previously underdeveloped land ([Achs 1992, p.64](#)). According to Nasseaur, Wang, & Dayrell, “Exurban large lot residential development accounts for the largest proportion of sprawl in America” (2009, p. 282), and growth in exurbia is outpacing that of urban, suburban, and rural development ([Storm et al., 2007](#)). The ability of an exurban landscape to provide ecosystem services is a fast-growing area of research in part because of the large amount of land that exurban landscapes consume and because of the potential for these landscapes to impact the ecology of a region. Concerns exist about landscape change leading to homogenization and lower ES provision, though evidence on actual landowner practices shows some variability ([Polsky et al., 2014](#)). In the mid-Atlantic regions of the US, exurban development has seen substantial expansion. For example, in the north-central Virginia and western Maryland regions, it is increasing on average 6.1% per year between 1986 and 2009 ([Suarez-Rubio et al., 2012](#)). According to [Theobald, 2005](#) (p.32), “urban/suburban housing densities will expand to 2.2% by 2020, whereas exurban will expand to 14.3%.” In

**Table 1.** Ecosystem service impacts delivered by home landscaping strategies.

Ecosystem Service Impacts	Delivered by (prior research)	Home landscaping strategy as demonstrated in landscape installation (this study)
Flood control	Improving precipitation infiltration and reducing runoff. (Bolund and Hunhammar, 1999; Pickett et al., 2001; Kowarik, 2005)	Created a vegetated bioswale. Increased vegetation by planting at high densities. Altered maintenance procedure (i.e. infrequently mown turf).
Water quality	Improving precipitation infiltration and reducing runoff. (Bolund and Hunhammar, 1999; Pickett et al., 2001; Kowarik, 2005)	Installed rain gardens. Included dense ground cover plantings (i.e. <i>Carex</i> sp.). Included native shrubs and groundcovers.
Plant diversity for wildlife	Increasing on site plant diversity by 500% by including 59 new species of native plants. (McKinney, 2008)	Reduced lawn. Increased planting beds. Added vertical vegetation layers. Increased area dedicated to planting beds. Increased native plants – trees, shrubs, and groundcover.
Lower air temperatures	Trees reduce air temperatures (Huang et al., 2009) and humidify the air through transpiration (Jarvis and McNaughton, 1986)	Planted a variety of large trees.
Less energy used	Trees reduce building energy use (Heisler, 1986; Akbari et al., 2001)	Use deciduous plants on south and west sides to shade buildings.
Less mowing	Lawn size reduction has positive effect on air quality and noise pollution	Reduce lawn size.
Moving indoor activities outside	Strolling and enjoyment of garden promoted to mood and concentration (van den Berg et al., 2003)	Create outdoor use areas through the architectural use of plants (Booth, 1983). Connect use areas with pathways.

**Table 2.** Non-Ecosystem service impacts and related demonstration landscape characteristics.

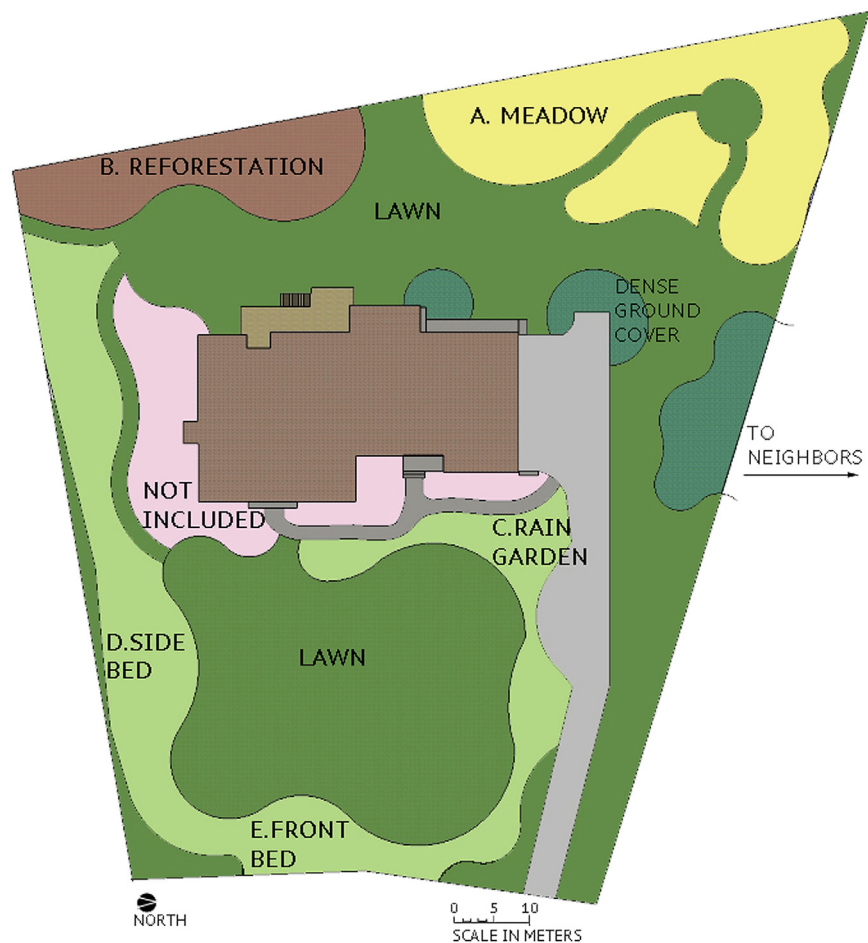
Non-Ecosystem Service Impacts	Demonstration Landscape Characteristics
Undesirable wildlife may be present	Additional native plant habitat hosts desirable species but also increases the likelihood that undesirable wildlife may be present.
Greater initial establishment cost	Represents 1–2% of the value of the property, approximately \$32,000.
Longer establishment time than turfgrass	Full realization of the aesthetic and functional benefits takes several years.
More weeding	As planting beds are created more weeding must take place until plants cover the ground.
No hardwood mulch in needed	Shredded leaf mulch used initially until plants covered the ground and then less mulch is required.
Leaves must be managed	Leaves may blow out of beds impacting homeowner, neighbor, and some aesthetic preferences.
More long-term tree care costs	Trees require pruning and dead or diseased trees must be removed.
Requires minimal pruning	Managing native plants in their natural form, replacing the shearing of plants (Welsh and Janne, 2008).
Requires more education	Homeowners may have to understand different fertilization patterns (in the fall only), recycling of grass clippings and fallen leaves, naturalistic pruning, and how to identify plants for hand weeding.
Looks different	The intervention landscape contrasts with a prevailing aesthetic.
Fewer clean lines	This type of landscape is less formal, with fewer pruned plants and results in a more naturalistic appearance, which may be perceived as unmanaged.
Less lawn for sports	The design incorporated contiguous lawn areas in the front and back yard to minimize this disamenity.
Enhances curb appeal	Average of 3.5–12% increase in property value is reported as a result of a sophisticated, complex, or otherwise diverse landscape (Behe et al., 2005; Anderson and Cordell, 1988; Luttik, 2000).

Delaware, housing development has concentrated in coastal communities and exurban areas, where low density and large houses on lots that often exceed one acre characterize developments. These landscapes are capable of supporting biodiversity that may contribute to regional ecological stability, but they are generally landscaped with conventional characteristics such as foundation plantings and large areas of mown turf. This study uses survey data to examine a large collection of ESs in addition to the other amenities and disamenities of an ecologically designed landscape.

## 2. Methods

### 2.1. The study site

In fall 2009, students designed an intervention for an exurban landscape (see Fig. 1). The site comprised the plantable space of a single 1.2-acre residential lot located in the Lower Brandywine Creek (Hydrological Unit Code 020402050403)



**Fig. 1.** Ecological design for landscape intervention.

of the Delaware Bay Watershed in Delaware, USA. The design demonstrates a set of ES that was implemented into the actual site in the spring 2010 (See [Table 1](#)). Pre-intervention, the plantable space was 98% turfgrass and 2% in six different tree species, foundation shrubs, and ground covers. The area receives 1092 mm of precipitation per year, with relatively similar monthly averages between 68.07 mm and 119.38 mm ([NOAA, 2013](#)). Site grading from home construction directed water flow from a high point near the residential street through swales, which led to a vegetated bioswale on one side of the house and to an off-property stream on the other side of the house. The site was unique in that it was graded to accept stormwater rather than diverting it to storm sewers. The development has a series of bioswales to collect stormwater after it flowed through residential landscapes. Grading problems resulted in poor stormwater drainage on site and standing water in several areas post-precipitation event. Pre-intervention, landscape management primarily involved mowing turf and pruning foundation plants. Few native plants were present, and because of the predominance of turf, minimal ES impacts were provided. The researchers designed, installed and managed the landscape for 1.5 years before “after” photographs were taken. Before and after photographs visually linked the intervention to ES impacts used in the survey (for further details on the intervention, see [Duke et al., 2014](#)).

The landscape intervention introduced contemporary landscape practices to a traditional home landscaping with the goal of highlighting various ES impacts. The homeowner had a desire to maintain prevailing community features and overall curb appeal through careful design—especially with respect to the front yard. Intervention goals included: reducing the lawn-to-plantable-space ratio, while maintaining enough lawn for circulation, play, and entertaining; increasing plant diversity by 500%; introducing a meadow (6000 ft<sup>2</sup>) and reforestation (3,000 ft<sup>2</sup>); modifying planted landscape beds to help mitigate stormwater runoff and increased on-site water filtration; and modifying management of turf on steep slopes.

The intervention neighborhood was a “development,” a term for a land-use pattern common in the USA where a former farm is subdivided and largely homogeneous houses are built. Houses are placed in the middle of relatively large lots often along curved streets. With only a few exits to other streets, these developments are partially isolated and do not always have sidewalks. Many find these land-use patterns desirable because the uniformity—often protected by legal covenants within the development and by local zoning—helps coordinate residential aesthetic and management expectations that coordinate autonomous land-use decisions and ostensibly protect property values. The plantable spaces are key drivers of uniformity, where turfgrass prevails and where all homeowners manage (or hire management of) relatively large landscapes. Typical management consists of regular mowing, with some pruning, fertilizing, and tree care. The study site was somewhat atypical for the region in that its development had comparatively larger



lots with houses that were more expensive than average. However, the setting was well suited for a large-scale residential demonstration site.

## 2.2. Individual interviews and pretests on landscape change

Survey instrument design exceeded one year, including pretesting and instrument refinements. Researchers extensively interviewed pretest respondents to capture how the general public best understands these landscape changes. Ultimately, 20 impacts were identified and were described in terminology (see the first three columns of [Table 3](#) for final terminology) revealed by the pretests as understandable, believable, and non-objectionable. Of particular importance was to use nonscientific language that residents would understand in a survey. To prevent bias, the intervention was described both in terms of the positive or negative utility changes, or benefits and costs; as discussed below, pretest interviews determined the most reasonable language was “good and bad for my household.”

## 2.3. Financial costs of the intervention

[Table 4](#) summarizes the intervention’s installation and maintenance costs. Between February 1, 2012, and April 17, 2013, 89 h of volunteer work created the installation and is priced at prevailing wage rates. Those labor costs, coupled with materials, supplies, equipment, subcontractors, and a standard markup totaled \$31,932. Maintenance costs included 230.1 h of volunteer labor plus materials for a total of \$6,921 and represent typical maintenance costs for this type of landscape in the first year after installation. As most labor following installation was devoted to weeding, these costs are anticipated to decline as the landscape matures.

## 2.4. Survey protocol and sample

Enumeration through intercept interview occurred on weekdays from July 8–15, 2013, at the two Departments of Motor Vehicles (DMV) in New Castle County, Delaware. A team of seven trained student enumerators, wearing University apparel, conducted the survey. Enumerators used a sign and poster displaying information and color photographs about the intervention. Respondents were selected randomly; each adult who entered the DMV was approached as a participant, unless all the enumerators were busy conducting a survey when a person entered. Screening questions were asked to ensure the sample was random and represented as closely as possible the target population, which was county residents at least 18 years old. An additional screening question determined whether the potential respondent came to the DMV to renew a driver’s license. Driver’s licenses were the randomizing mechanism used to sample the target population, an approach successfully used in other research to intercept an

**Table 3.** Ecosystem services and other impacts of the landscape intervention (with hypothesized sign).

Type of Impact	Impact as Described in Survey Instrument	Abbreviated Impact Name	Hypothesized Impact on Public	Mode Result
Ecosystem Service	1. Better flood control	Flood control	+	+
	2. Better water quality	Water quality	+	+
	3. More plant diversity for wildlife	Plant diversity	+	+
	4. Lower air temperatures providing cleaner air	Lower temperatures	+	+
	5. Less time spent mowing	Less mowing	+	+
	6. Less energy used due to shaded buildings	Less energy	+	+
	7. Moves indoor activities outside	Indoor activities outside	+ or 0	+
Indirect Ecosystem Service	8. Undesirable wildlife might be present (ticks, deer, snakes, etc.)	Undesirable wildlife	-	-
Installation	9. Greater initial cost of establishment	Establishment cost	0	0
	10. Takes time to become established	Establishment time	-	0
Management	11. More weeding initially until plants cover the ground	More weeding	-	0
	12. Leaves must be managed and may blow out of beds	Leaf management	-	0
	13. No hardwood mulch needed because on-site leaves used as mulch	No mulch	0	+
	14. No sheering of plants required, just minimal pruning	No sheering	- or 0	+
	15. Education required for proper management	Education	- or 0	+
	16. Long term tree care required (disaster and disease removal)	Tree care	0	+
Aesthetics	17. Fewer clean lines and order in the landscape	Fewer clean lines	-	+
	18. Less lawn for sports	Less lawn for sports	-	0
	19. Higher curb appeal and increased property value	Curb appeal	+	+
	20. Looks different from neighbor's lawn	Looks different	-	+

These terms are exactly as they appeared on the public preference survey. These impacts are abbreviated in the remainder of the paper. A series of focus groups and pretests were used to revised these terms so that they would be understandable to the general public. ES indicates “Environmental Service”. For mode hypotheses, “+” is “good”, “0” is “neither”, and “-” is “bad”.

**Table 4.** Installation and Maintenance Costs of the Intervention.

	Hours	Establishment Costs	Hours	Maintenance Costs
Plant Materials		\$13,727.13		\$1,161.63
Labor @ (\$12.44/h)	295	\$3,669.80	230.1	\$2,862.44
Subcontractor costs	185.5	\$8,044.25		
Equipment		\$113.11		
Supplies		\$535.34		
Multipliers		**		x1.72*
Total Costs		\$31,931.86**		\$6,921.41*

Mean hourly wage = \$12.44 from Bureau of Labor and Statistics. Occupational Employment Statistics: 37–3011 Landscaping and Groundskeeping Workers <http://www.bls.gov/oes/current/oes373011.htm>.

\*Includes mark up of 1.72 calculated based on job costs = 58% total revenue; 32% overhead; and 10% profit on materials, labor, equipment and supplies.

\*\* Includes mark up of 1.72 and 10% profit on subcontractor costs.

approximately random public sample (i.e., [Borchers et al., 2007](#)); most adults have licenses, and their renewal date is based on their birthdays, which lacks a systematic selection pattern. Ineligible respondents were excluded; however, the randomization process did not work perfectly with about 1/6th of the sample. The signage attracted interest, and some self-selected by seeking to complete a survey. These respondents were not renewing a driver's license, so the selection was noted and the respondent was interviewed. In the end, a large majority of the sample was drawn from a random sample of adult drivers. The enumerators did not collect any personally identifiable information about the respondents. The university Institutional Review Board approved the research protocol.

One enumerator provided an individualized, guided survey for each respondent. Eligible respondents agreed to participate in the survey via an informed consent, which also described the broader project and its funding source. The enumerator offered a verbal description of the landscape intervention using the poster as a visual aid. The intervention was described in both positive and negative terms using a consistent list of “pros and cons” in language that was developed and deemed credible during pretesting. Then, depending on the preference of the respondent, the enumerator would either read the survey—asking the respondent for answers—or let the respondent fill the survey out on their own. At all times, the respondent could ask clarifying questions of the enumerator.

As shown in [Table 5](#), 323 people were asked to participate in the survey, but 202 declined, yielding an intercept response rate of 37.5%. Of 121 respondents, 105 completed the survey fully and constitute the final, usable sample. Included in the 121 respondents were 20 self-selectors all of whom were retained in the sample, in

**Table 5.** Survey Response.

	Male	Female	Total
Respondents Intercepted	199	124	323
Participants	73	48	121
Refusals	126	76	202
Response Rate	36.7%	38.7%	37.5%
Self-Selectors	8	12	20
Percent Of Participants Self-Selecting	11.0%	25.0%	16.5%
Usable Surveys	60	45	105

part, because they helped correct for an over-sampling of males. At the end of the survey, respondents answered demographic questions privately before inserting the anonymous survey into a large box. The demographic data show that respondents ranged in age from 18 to 79 years old, with an average age of 41.3 and a median of 37. There was some reported confusion on the demographic question about highest level of education (see [Duke et al., 2014](#)), so researchers only know that 10.5% had a high school education or lower, while 89.5% graduated high school.

## 2.5. Preference questions, hypotheses, and data analysis

The first survey question asked where the respondent lived in relation to the intervention neighborhood. Then, the survey asked two preference questions (#2 and #3) and an open-ended question (#4). For all 20 impacts, question 2 asked respondents to assess whether it is:

Good: “It’s good for my household”

Neither: “It’s not good or bad for my household”

Bad “It’s bad for my household”; or

Doesn’t Affect: “I don’t care about this for my household.”

This terminology seems colloquial, but it was repeatedly tested and refined during pretests and debriefing interviews. Respondents were most comfortable with these constructs, and they match an economist’s understanding of positive utility, negative utility, and indifference. This approach is similar to at least one other article’s conceptualization of landscape preferences: [Nielsen et al. \(2012\)](#) used the “like, dislike, and unseen” attributes.

Importantly, the survey offers two different choices other than good/bad. “Neither” and “doesn’t affect” allow respondents to express two different forms of lack of preference: indifference and non-applicability. As the hypotheses in Table 3 make

clear, some impacts should affect all respondents—mainly the ES impacts—and some should not affect most respondents—mainly, the management impacts. Unfortunately, enumerators reported that some respondents were confused asking about an intervention on a specific site in a specific neighborhood. For a minority of respondents, enumerators decided the survey lacked salience and thus allowed ad hoc reframing of the preference question so that the intervention was instead hypothetical, occurring in the respondent's neighborhood. Enumerators reported that most respondents answered in the intended manner so they were revealing preferences for the intervention at the specific location where it occurred and in relation to their household location. If this failed, then the enumerators reported rephrasing in terms of preferences about the respondent's neighbors adopting a similar intervention. In a few cases, enumerators reported being forced to further reframe in terms of the respondent's preferences for pursuing the landscape themselves. Debriefing the enumerators suggested that a large majority of respondents accepted the intended interpretation. Future studies ought to develop a measure of salience, thus allowing control over different interpretations in the data analysis. These ad hoc adjustments were not recorded, so they could not be examined separately; but they are unlikely to affect the ES questions at the heart of this paper because ESs are primarily public goods.

Question 3 offered the same list of 20 impacts as question 2, but asked respondents to prioritize both good and bad impacts: "What are the three most important beneficial impacts on your quality of life?" and "What are the three most undesirable impacts on your quality of life". Respondents were to order each type by the numbers 1, 2, and 3, in order of most beneficial or most undesirable. The survey also allowed for written elaborations of question 3 in an open-ended question 4 that describes the respondent's written explanation of the most beneficial aspect of the intervention to society. This paper focuses on questions 2 and 3, and additional results are in [Duke et al. \(2014\)](#).

**Table 3** lists the hypothesized impacts in terms of the most common response category, or mode. The researchers hypothesized that all but one ES services would tend to be perceived as beneficial to the general public. One does not expect that many would be affected by moving indoor activities outside, so this impact was anticipated to be either neither or beneficial. Researchers strongly anticipated that undesirable wildlife would be perceived to be negative. For most of the establishment and management impacts, researchers hypothesized that most respondents either would not care (as the impacts are primarily felt by the homeowner) or see the change as somewhat negative. For the key aesthetic measures, researchers hypothesized that respondents would perceive most of the effects as negative (looks different, fewer clean lines, and less lawn for sports), while another would be positive (curb appeal). Positive curb appeal was anticipated because respondents viewed pictures to provide confidence in the intervention's

careful design and implementation. Researchers anticipated substantial preference heterogeneity.

### 3. Results

#### 3.1. Locational results

The respondents were told the name and location of the intervention's development neighborhood. Question 1 sorted respondents into (1) those who do not live in and have never visited the neighborhood; and (2) those who do not live in but had visited the neighborhood. None of the 105 respondents lived in the intervention neighborhood, but 24.8% said that they had visited it. A demographic question asked respondents to mark their housing location with an "x" on a map of the county (scale 1 mm = 0.22 miles). We then measured the distance of the respondent's residence from the intervention. The minimum distance was 0.7 miles, the maximum was 8.5 miles, and the median was 7.0 miles. Further, we estimated the respondents' home watersheds to see if they were likely to benefit directly from the intervention's impact on water quality. Only 8.6% were in the Lower Brandywine Creek, but 99.1% were in the same Watershed (Delaware Bay). The spatial measures indicate that although the sample households vary in location, none were located in the neighborhood. These locations suggest most respondents would view these changes as public goods.

#### 3.2. Preferences about landscape impacts

Table 6 presents the survey preferences for each impact in question 2. The most important result is that the top six ranked impacts, in terms of percent rated "good", were ES impacts. And, the other ES impact was ranked eighth, so that seven of the top eight impacts were ES. Moreover, the percentage reporting these impacts were "good" was very high (68.0%–89.5%), while the "bad" percentages were very low (1.0%–6.8%). Although a small minority reported that the ES impacts had no effect or was neither good nor bad, the large majority of respondents reported favorable responses. This result clearly suggests the public recognizes, values, and prioritizes the intervention's ES impacts in terms of how this affects their household wellbeing.

As anticipated, "undesirable wildlife" received the lowest ratings. A plurality (46.7%) rated it negatively, only 16.2% rated it positively, and 28.6% rated it "neither". Thus, almost all (91.4%) responded that they were affected. The results offer strong evidence that the indirect ES of undesirable wildlife is important to the public and potentially will prevent landscape interventions from being widely accepted. The remaining impacts mostly were rated between the two extremes. A majority rated curb appeal, looks different, no sheering, and no mulch as positive. Less lawn for sports and more weeding were the only two impacts where the "bad"

**Table 6.** Survey Data on Overall Assessment of 20 Impacts of the Intervention.

Impact	Good (%)	Bad (%)	Neither (%)	Doesn't affect (%)	Qualitative Categorization
Less energy	89.5	2.9	4.8	2.9	<b>Strong Amenity</b> More than 76% rated “Good” Less than 4% rated “Bad”
Water quality	83.8	1.9	9.5	4.8	
Lower temperatures	83.7	1.9	12.5	1.9	
Flood control	79.0	1.9	16.2	2.9	
Plant diversity	78.1	3.8	16.2	1.9	
Less mowing	78.1	1.0	18.1	2.9	<b>Amenity</b> More than 46% rated “Good” Less than 10% rated “Bad”
Curb appeal	76.2	0.0	21.0	2.9	
Indoor activities outside	68.0	6.8	18.5	6.8	
Looks different	65.7	3.8	21.9	8.6	
No sheering	61.9	4.8	25.7	7.6	
No mulch	56.7	4.8	27.9	10.6	<b>Fair</b> Number rating “Good” is 10–25% more than number rating “Bad”
Education	46.7	9.5	36.2	7.6	
Tree care	43.8	18.1	33.3	4.8	
Fewer clean lines	38.1	17.1	37.1	7.6	
Establishment cost	31.4	25.7	34.3	8.6	
Leaf management	30.5	24.8	35.2	9.5	<b>Contentious</b> Number rating “Good” is within 10% of number rating “Bad”
Establishment time	28.2	12.6	47.6	11.7	
More weeding	23.1	26.0	37.5	13.5	
Less lawn for sports	20.0	26.7	36.2	17.1	
Undesirable wildlife	16.2	46.7	28.6	8.6	

Ordered by highest positive response. Rows do not necessarily sum to 100.0% because of rounding.

ratings outweighed the “good” ratings. Most impacts received substantial positive/negative preference ratings with only four impacts where 10% or more said they were unaffected: no mulch, establishment time, more weeding, and less lawn for sports. The most surprising result was that 76.2% rated the curb appeal impact as “good” and no one rated it “bad”. This offers some evidence that this carefully designed landscape did look better (and would increase property values more) than the standard turf landscape.

Table 3 offers the mode results in the column next to the hypotheses. All seven ES impacts and the undesirable-wildlife impact matched hypotheses. The mode response for many of the other impacts was more favorable than anticipated, suggesting that the intervention may be more acceptable than anticipated. For instance, presumably negative impacts for the public (more weeding, leaf

management, establishment time, and less lawn for sports) were actually rated “neither” most frequently. Also, several impacts expected to be negative (no sheering, education, looks different, and fewer clean lines) were actually rated positively by a plurality. The latter result involves aesthetic issues, which suggests, surprisingly, that the homogeneous turf landscape may not actually be perceived as the most pleasing by a plurality of respondents.

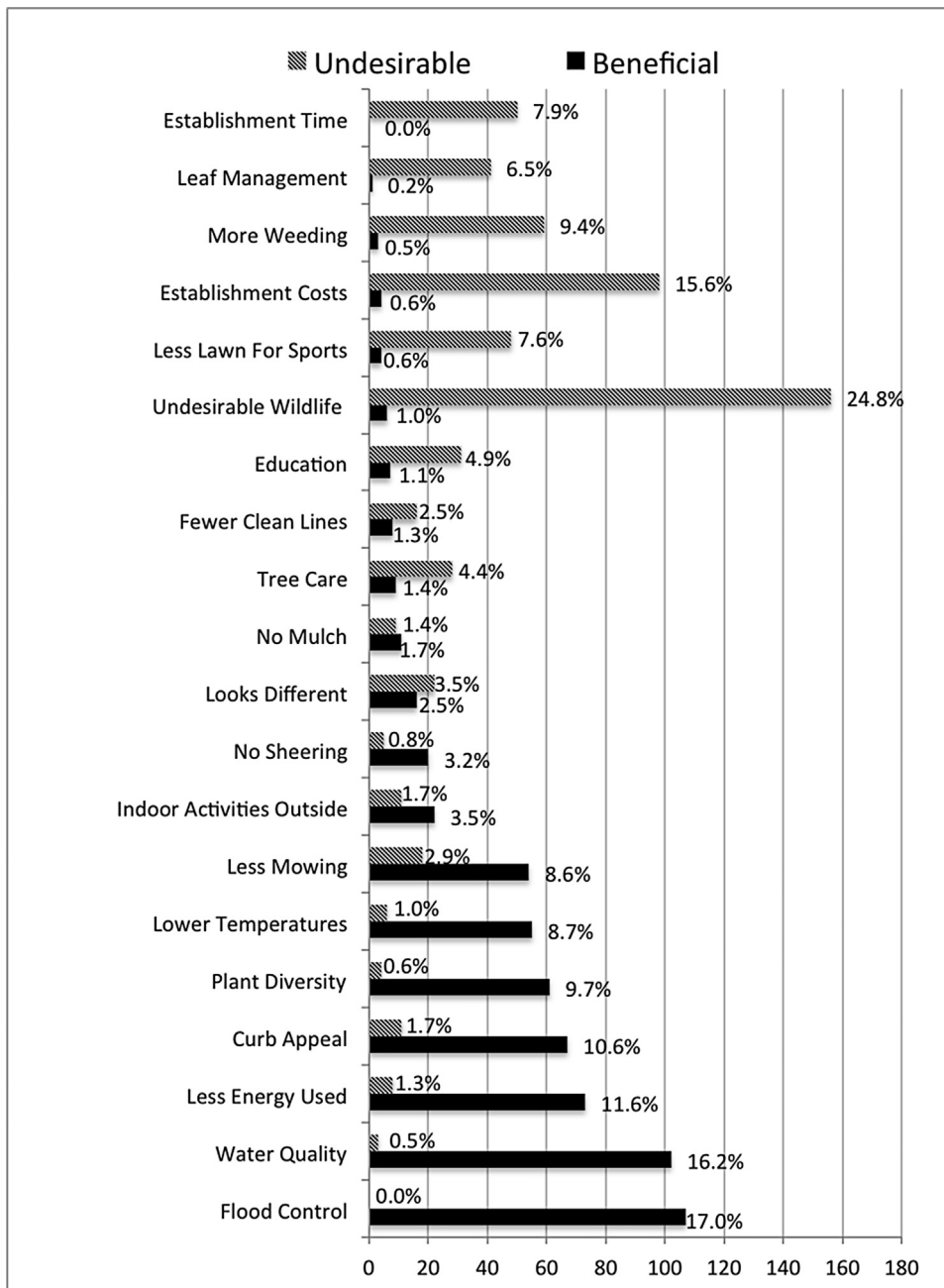
### 3.3. Qualitative assessment of preference heterogeneity

Although the mode results show majorities and pluralities of preference, they poorly capture preference heterogeneity. Qualitatively, an impact is more acceptable when those not rating it positively instead rate it as “neither” or “doesn’t affect.” To compare heterogeneity, we divided the results into five ad hoc, but qualitatively different, categories based upon how many rated “good” versus “bad”. Table 6 also presents the descriptions and results. The best impacts were termed “strong amenities,” showing nearly universal appeal because of a high percentage of “good” ratings (over 76%) and a very low percentage of “bad” ratings (under 4%). Similarly, the “amenities” were impacts with more than 46% “good” and less than 10% “bad”. “Fair” impacts were classified as having substantially more “good” than “bad” ratings, while “contentious” impacts had about the same “good” and “bad” ratings. This classification suggests only one “clear disamenity”, which was undesirable wildlife. In addition, all but one of the ES impacts were deemed “strong amenities” and the other ES impacts, indoor activities outside, was an “amenity”. These results suggest that most people expect to benefit from most impacts of the intervention, and the impacts with the clearest support, “strong amenities,” are associated with ESs. Yet, the results also show that undesirable wildlife is a “clear disamenity.”

### 3.4. Most beneficial and most undesirable impacts

The preceding results from question 2 do not reveal preference intensity, but question 3 allows prioritization of three good and bad effects. To compare question-3 results, the prioritization ranking was coded in terms of cardinal preference “points.” Impacts ranked third most beneficial were given 1 point, the second most beneficial 2 points, and the most beneficial 3 points. All 105 respondents were, in effect, allocating 6 points for beneficial because they each assigned impacts of 1, 2, and 3 points—with the same process used for undesirable impacts. To compare how these prioritizations were made, the researchers calculated the percent of the 6 possible prioritization points (for the sample, the total was 6 point x 105 respondents = 630 points) that were allocated to each impact. Fig. 2 shows these results, where all the beneficial prioritization percentages sum to 100%, as do the undesirable prioritization percentages. Note





**Fig. 2.** Data on Most Important Beneficial and Undesirable Impacts.

that respondents were only able to assign the highest ranking (3 points) to one impact, so the highest possible point total is 315 or 50% in Fig. 2.

Fig. 2 shows clearly that undesirable wildlife had the greatest impact on people's quality of life, and the effect was almost completely negative—24.8% of the possible undesirable points and about half of the maximum possible for any one impact. In other words, undesirable wildlife was so important that on average

respondents scored it 1.5 points. A few of the impacts had a mixture of undesirable and beneficial prioritization ratings (for example, no mulch and looks different), but the overall points allocated were small. On the positive side, impacts dealing with water (water quality and flood control) were prioritized positively. Together, the water impacts accounted for 33.2% of possible beneficial points with almost no undesirability. Together, the seven ES accounted for 75.3% of the potential beneficial points, while only 8.0% of the possible undesirable points. Thus, the most important impacts of the intervention are associated with ES, and the most undesirable impact is the indirect ES of undesirable wildlife.

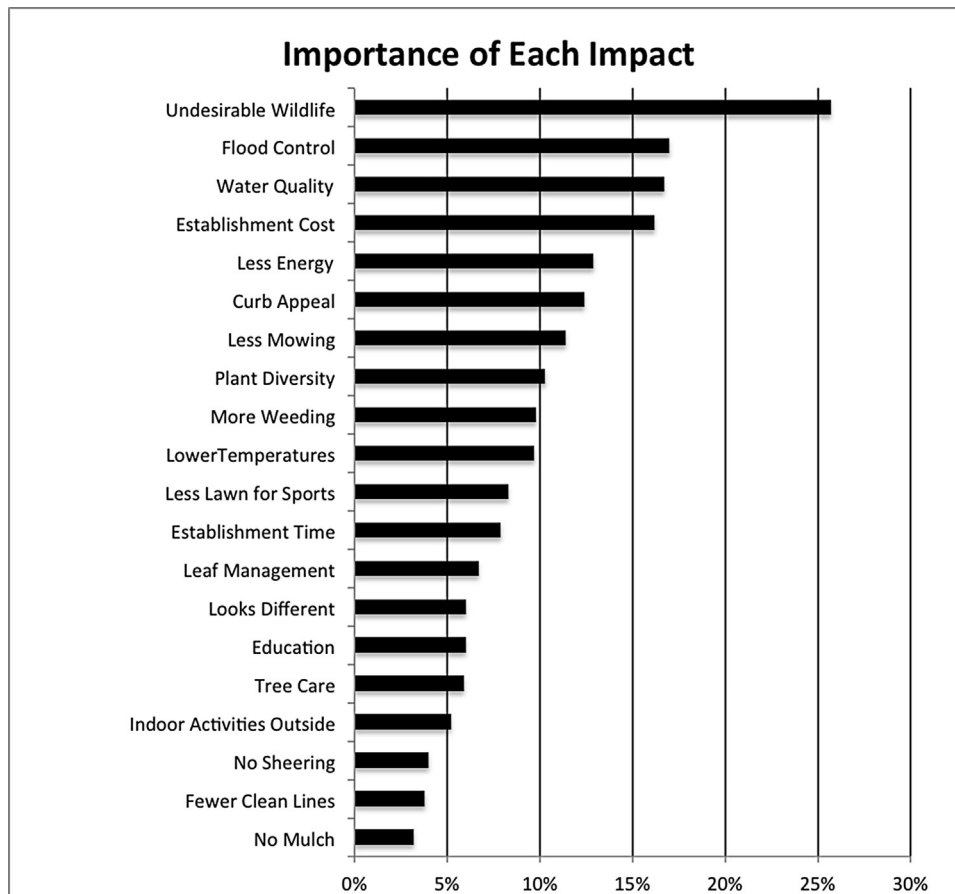
The aesthetic impacts had unexpected results. Curb appeal was relatively important (10.6% of beneficial points), as was less lawn for sports (7.6% of undesirable points). Fewer clean lines and looks different had minimal prioritization. Taken together, the four aesthetic impacts accounted for 15.0% of the beneficial points and 15.3% of the undesirable points. On balance, one will have difficulty determining conclusively whether the intervention is good or bad aesthetically because the aesthetic amenity and disamenity effects cancel out. By identifying 20 impacts, this study isolates aesthetic impacts and show how, on balance, they have no effect.

### 3.5. Overall importance of intervention impacts

To better compare positive and negative prioritization results, the analysis identifies the raw overall importance for each impact, i.e., how much of the public's attention will be focused on any given impact. Adding the prioritization points for both undesirable and beneficial offers a measure of overall importance (out of 200%). Fig. 3 shows the importance of each impact in descending order. The impacts near the bottom of the graph have a lower level of importance on respondents' quality of life compared to those near the top of the graph. The top quartile of "important" impacts includes undesirable wildlife, flood control, water quality, establishment cost, and less energy. These impacts account for 44.3% of importance, while the lowest quartile is only 11.1%. Once again, undesirable wildlife is most important, accounting for 12.9% of possible importance. The seven ES impacts account for 41.6%, with water impacts being most important while indoor activities outside is of very low importance. The aesthetic impacts are 15.3%, the management impacts are 20.1%, and installation is 12.1%. These results can also be viewed as a comparison of the strong amenities (45.2%) to the clear disamenity (12.9%).

### 3.6. Open-ended results

Question 4 allowed respondents to explain in an open-ended format what they thought was the most important benefit to society of the intervention. These



**Fig. 3.** Data on Overall Importance of Impacts on Respondent's Quality of Life.

answers were divided into four categories. The percentage of total open-ended answers is calculated, as there were unusable answers, blank answers, and some answers that fell in multiple categories. Most answers (76.2%) indicated that ESs were the most important benefit. Other answers included positive aesthetics characteristics (25.7%) and negative aesthetics characteristics (1.0%).

## 4. Discussion

### 4.1. Key findings and limitations

The most important findings are that the survey respondents are generally favorable about the specific landscape intervention and recognize that the most important impacts involved ES. This suggests that the public may recognize the link between more sustainable landscape choices and their welfare. Another important finding is that the way the public processes sustainable landscaping impacts seems to be multidimensional in that there are many impacts both beneficial and undesirable and of varying importance. Therefore, public

preferences on ES landscapes may be complex. Although the most important impacts of sustainable landscape transitions are indeed associated with ES, the public tends to have a divided opinion about the benefits (seven positive ES) and the costs (undesirable wildlife). This implies that the framing of the land use land cover change will substantively affect planning debates. If some amenities or disamenities are not mentioned, the planning process may be biased. However, if all the impacts are highlighted, it may be difficult for the public to articulate a single opinion.

Existing landscape preference studies take on many different forms—often targeting water saving with xeriscaping and providing enhanced habitat. Our study suggests that it is important to acknowledge a full slate of multidimensional impacts because the public tends to recognize more impacts than the research may expect. Indeed, in this study, the hypothesized effect of “doesn’t affect” was selected less than expected. Our study likely benefited from its real-world landscape change linked to the preference survey because it provided region-specific credibility and salience for the sample.

The study has limitations. Some respondents had difficulty understanding the way this type of landscape management can affect their quality of life. This resulted in a subset where the questions were reframed so that the respondents could see how it affects their quality of life. The key obstacle was the spatial distance between the respondent’s household and the location where the landscape change occurred. A subset of respondents could only understand the effects if they made the change in their own yard or in their neighborhood. In retrospect, the researchers wish they had asked questions about salience and separately about whether homeowner-respondents would have considered pursuing this type of landscape on their own land.

## 4.2. Implications for policy and future planning research

In the U.S., few local policies and planning efforts directly impact local ES-land uses on private exurban landscapes. For instance, zoning ordinances rarely require quality habitat provision. In contrast, many aggressive zoning ordinances enforce contrary activities such as mowing tall grass that prevent meadows. Probably the leading local-ES efforts involve xeriscaping ordinances in the water stressed regions. Most government and nonprofit efforts to enhance locally provisioned ES such as water quality, water quantity, flood control, and habitat provision almost exclusively occur on public land or on private reserved land (such as open space dedicated in large developments). Future planning will likely play a more important role in local ES provision, if for no other reason than there is so little current effort.

Sustainable landscaping practices are not prevalent in Delaware or in most urban and exurban areas, where households having yards consisting of mainly lawn space and foundation plantings that consist of exotic species. However, our results raise doubts that this current landscape pattern matches public preferences. Public preferences in the study region reflect a desire for enhanced ES as delivered by the sustainable intervention. The majority of the impacts had a positive effect on off-site households rather than a negative effect. Improvements involving water quality and quantity are the most-important, positive impacts. In isolation, the water results suggest that Delaware residents desire better water management practices in their landscape.

Although strong ES preferences were found, the results are insufficient to direct policy and are only suggestive for future studies. The study identified the relative preference and importance of landscape impacts but not their relative benefits and costs. Although it may seem that preferences for the beneficial ES likely balance or exceed the negative aspects of landscaping intervention, without economic welfare measures one cannot be sure that sustainable landscaping enhances welfare. Nonmarket valuation research is needed before an optimal mix of landscape attributes can be selected using marginal cost, marginal benefit, and synergistic measures; without nonmarket valuation measures, the benefits and costs cannot be compared commensurately. In addition, although preferences were stated relative to the intervention's well-defined landscape change, the attributes of the study do not vary in an experimental framework—for instance, there are no treatments varying the square feet of meadow. Further, the ES impacts were described qualitatively instead of in quantitative measures of environmental change—i.e., reduce X lbs of nitrogen entering off-site waterbodies. The research therefore cannot inform the optimal intensive and extensive margins of the intervention. Similarly, the results do not reveal whether a different optimal intervention would be appropriate in a different location. The study only targeted the broader “public,” seeking to inform the public good aspects of ES, but not the neighbors and owners themselves. These latter groups would be expected to receive more direct impacts and be responsible for installation and management, and so the pattern of their preferences and direct fiscal costs incurred requires a different survey instrument.

These qualifications warrant additional research prior to developing an optimal planning effort. However, whatever the form, this planning effort will have to overcome two realities. First, owners themselves do not likely value sustainable landscaping at a level above the costs, which means that wholesale landscape conversions are unlikely to occur without external incentives. It is possible, however, that incremental sustainable changes may be more acceptable to owners. Additionally, [Martini and Nelson \(2015\)](#) find that owners with more knowledge about lawn management are more likely to manage in a way that provides ES. Second, developments have restrictive covenants that prevent some sustainable

landscapes. The fact that sustainable landscaping is rare suggests that most owners receive private benefits of personal enjoyment and possible enhanced sale price below the fiscal costs of installation and management and, as Nassauer et al. (2009) find, the peer impacts or costs of violating neighborhood norms. This study offers some evidence on these impacts, though more research is needed. For instance, establishment cost was one of the three most undesirable effects of the intervention and the fourth most important impact. Data on installation and management costs show that this type of intervention likely will cost tens of thousands of dollars.

Landowners therefore will likely need incentives for broad adoption. If there are social net benefits, then an optimal tax could incentivize land use land cover change: An impact fee on new developments that do not install sustainable landscaping or a subsidy for those that do. Education and evolving resource scarcity may also play an important role in adoption, as both affect the owner costs (more knowledgeable owners, say, will face lower management costs) and the public (who will increase their value of the beneficial impacts) (see Martini and Nelson, 2015). Future induced innovation also will help attenuate the received costs and benefits. For instance, owners could attenuate the undesirable-wildlife impact by making averting expenditures on raccoon-proof trashcans. From pretesting, survey results, and post-intervention tours, the researchers find that people are most concerned with the risks of undesirable wildlife, likely because this has a direct health threat. The researchers believe this to be the most important obstacle to sustainable landscapes on private land. In addition to education and averting expenditures, planning efforts should recognize that risk is more acceptable when the “victim” controls the decision that increases the risks. Innovative policy ought to allow the owner to select the level of risk exposure. That said, risk is complicated in this setting because neighbors involuntarily endure an owner’s choice about voluntary exposure. Coordination results from game theory may be useful. Future research may help understand exactly how the risks (and benefits) are absorbed. For instance, a study could use experimental design to study how risk perception varies with an increase in relative distance from the risk (i.e., how far placing a small meadow away from a home within a development affects owner and neighbor adoption of that landscape treatment). Finally, it is important to recognize that the scale of this intervention was much larger than is feasible for most homeowners. Future research ought to investigate how neighbors and the broader public accept smaller-scale efforts, which provide fewer services.

## 5. Conclusions

This paper describes research on a sustainable landscape intervention in Delaware that altered a residential landscape in order to enhance ecosystem services. The landscape intervention occurred in exurban New Castle County, Delaware. The affluent neighborhood has houses with large yards, but the intervention reduced

lawn from 98% to under 50%. Native plants and various land covers were introduced, including a constructed forested area and separate meadow. With this landscape intervention came many ecosystem services including water quantity and quality improvements, aesthetic changes, and expanded habitats. The intervention cost approximately \$32,000 to establish. Though high, this cost aligns with landscaping costs in similar affluent neighborhoods. An intercept survey of residents (non-neighbors) was conducted to understand public preferences for this type of intervention, particularly the off-site received costs and benefits of the altered ES. The survey data show the ES changes were perceived to have a positive impact on people's quality of life, though some other impacts had a negative, a positive, or no effect. The most important impacts were found to be: undesirable wildlife (negative); flood control (positive); and water quality (positive).

The research suggests that the rarity of sustainable landscapes may not be due to preference for traditional yards with extensive lawn space. Rather, there may be a mismatch between public benefits and landowner costs. Residential landowners substantively affect water quality and the provision of ES. Yet, residential landowners make land management decisions that are largely free from government regulations protecting water quality and other ecosystem service provision. Autonomy arises from historical norms and local laws that locate many on-parcel decisions firmly within the landowner decision space. However, as scientists gain an increasing appreciation of the interconnectedness of ecosystems, continued autonomy carries a cost. Economically, residential landowners are interdependent decision makers, who do not bear the full costs nor receive the full benefits of their actions. This means that activities that degrade ES will be oversupplied and those that enhance ES will be undersupplied. In short, there is a suboptimal, sustainable landscape allocation problem. The cumulative water quality and ES impacts of numerous residential decisions are likely significant. However, current planning has no solutions to offer and more research is needed to inform the impacts of these interconnected decisions. Despite these challenges, a relatively simple policy, such as a tax or subsidy, could incentivize more sustainable practices.

## Declarations

### Author contribution statement

Joshua M. Duke, Jules Bruck, Susan Barton: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Megan Murray: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Shreeram Inamdar, Douglas W. Tallamy: Conceived and designed the experiments.

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### **Competing interest statement**

The authors declare no conflict of interest.

### **Additional information**

No additional information is available for this paper.

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